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Biological Diversity of Kingdom Animalia at the Hakri River, Hapcheon-gun, Korea

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Abstract— **This study was conducted the ecological biodiversity of animals and analysis of environmental factors at the Hakri River in Korea during 2015 season. The fauna of four surveyed stations was a total of 69 taxa, representing five classes. Birds (Aves) exhibited the greatest species diversity with 20 taxa identified, followed by invertebrates (15 taxa); mammals with 12 taxa, reptiles/amphibians (Sauropsida/Amphibia) with 11 taxa, and fish represented by 11 taxa. Shannon-Weaver indices (H′) for mammals and birds at upper region were higher than those of low region. Richness indices for animal taxa were also varied among the stations and seasons. Although evenness indices for five animal kingdoms during seasons were different from each other, there were not shown significant differences ($p < 0.05$). Berger-Parker's index (BPI) for mammals was varied from 0.121 (invertebrates at Station A) to 0.304 (reptile /amphibian at Station A). The Bray-Curtis' distances were calculated from differences in abundance of each species according to geographic distances among four stations at the Hakri River. The relationship between a distance matrix and a quantitative environmental variable was shown very strong. The dendrogram showed two distinct groups; Station A and Station B clade and the other stations (Station C and Station D).**

Index Terms—**Biodiversity, fauna, spatial patterns, Hakri River.**

I. Introduction

The biological diversity defines the variability among living organisms from all sources including, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species, and of ecosystems [1]. The biodiversity is a contracted version of the term, biological diversity. Thus, biodiversity includes genetic variation within species, the variety of species in an area, and the variety of habitat types within a landscape. Perhaps inevitably, such an all-encompassing definition, together with the strong emotive power of the concept, has led to somewhat cavalier use of the term biodiversity, in extreme cases to refer to life or biology itself. But biodiversity properly refers to the variety of living organisms. Biodiversity is most frequently quantified as the number of species. Biodiversity at the species is most applied by ecologists and conservation biologists, although high levels classification (genera, families, orders) are sometimes also considered [2].

Alpha (α), beta (β), and gamma (γ) diversities are among the fundamental descriptive varieties of ecology, but their quantitative definition has been controversial [3]. Whittaker [4] proposed measuring β as the ratio between regional diversity or γ and αsuch that $H\gamma = H\alpha \times H\beta$. An alternative approach consists in measuring β-diversity with an additive model such as $H\gamma = H\alpha + H\beta$ [3, 5]. Most diversity indices may be considered generalized measures of uncertainty [6, 7].

River systems are the zone of Earth's highest biological diversity – and also of our most intense human activity. Freshwater biodiversity is in a state of crisis, a consequence of decades of humans exploiting rivers with large dams, water diversions and pollution. Freshwater species are even more endangered than those on land. Many river or stream biomes are severely threatened though. Most humans fail to realize just how beneficial they are to the environment [8]. As a result, they end up trying to destroy them and then build on those areas. In fact, some refer to the reservoirs as the wastelands. They are often drained and then used for other purposes. Not thoughts are given to the forms of plant and animal life that reside in them.

The Hakri River is started at the mountains and ends at the Yangcheon River. Sustainable management of this river in agriculture is critical to agricultural production. In addition, the river has been shared with other users and maintained the environmental and social benefits of water systems.

The purpose of this study is to investigate the fauna on the Hakri River at four regions during four. I suggest appropriate criteria for a biodiversity measure when that measure is to be used primarily to assess changes in biodiversity over time. This provides an objective means of choosing between possible measures.

II. Materials and Methods

2.1 Surveyed regions

This study was carried out on the Hakri River, located at Samga-meon province (upstream region: 35°399′466″N/128°079′504″E, low-stream region: 35°393′860″N/128°086′231″E), Hapcheon-gun in Korea (Fig. 1). The areas of this river is located at low altitude (100~110 m above sea level) and consists of a mosaic of agricultural fields and farming houses. The upper regions are surrounded by pine forests including *Pinus thunbergii* and *Pinus densiflora*. The slopes of river are very low (average < 5°). In this region the mean annual temperature is 13.0℃ with the maximum temperature being 19.8℃ in August and the minimum 7.3℃ in January. The annual average precipitation of this region is approximately 1,276 mm, and sometimes, intensive rainfall such as 100 mm in an hour or 250 to 400 mm in a day can be recorded.

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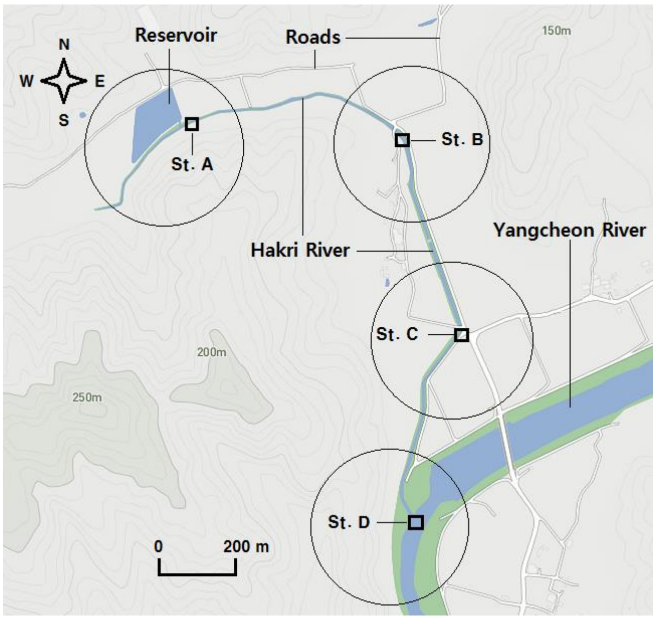

Figure 1: The four stations (St. A~D) for fish and invertebrat es (small quadrangles) and four areas (large circles) for mam mals, birds, and herpetology at the Hakri River, Korea.

2.2 Identification of animals

Animal identification using a means of marking is a process done to identify and track specific animals. A small dredge is also used to collect sediments from the bottom of the river to determine the numbers and kinds of invertebrates present. Identifications of mammals and herpetology were based on Weon [9]. Identifications of birds were based on Lee et al. [10] and Yoon [11]. Identifications of herpetology were based on Lee et al. [12], respectively. Identifications of fishes were based on Choi [13]. Identifications of invertebrates were based on Kim et al. [14] and Merritt and Cummins [15]. The periods of animal samplings were March, June, September, and December 2015.

2.3 Biotic indices

Diversity is defined as the measure of the number of different species in a biotic community. I assume that three aspects of biodiversity are of primary interest: number of species, overall abundance, and species evenness.

Shannon–Weaver index of diversity [16]: the formula for calculating the Shannon diversity index (H') is

$$H' = -\sum pi \ln pi$$

pi is the proportion of important value of the *i*th species (*pi* = *ni* / N, *ni* is the important value index of *i*th species and N is the important value index of all the species).

$$N1 = e^{H'}$$

$$N2 = 1/\lambda$$

Where λ (Simpson's index) for a sample is defined as

$$\lambda = \sum \frac{ni(ni-1)}{N(N-1)}$$

Species richness is the number of species of a particular taxon that characterizes a particular biological community, habitat or ecosystem type [17].

The species richness of animals was calculated by using the method, Berger-Parker's index (BPI) and Margalef's indices (R1 and R2) of richness [18].

BPI = *N*max/N where *N*max is the number of individuals of the most abundant species, and N is the total of individuals of sample.

Species evenness is a measure of biodiversity which quantifies how equal the community is numerically. Evenness indices (E1~E5) was calculated using important value index of species [19, 20].

ß-diversity index was calculated using the method of Tuomisto [21] as ß = γ/α. Here γ is the total species diversity of a landscape, and α is the mean species diversity per habitat. The homogeneity of variance or mean values to infer whether differences exist among the stations samples or seasons was tested [22]. Except where stated otherwise, statistical analyses were performed using the SPSS software (Release 21.0).

2.4 Cluster analyses

A dendrogram was constructed by the neighbor joining (NJ) method using the NEIGHBOR program in PHYLIP version 3.57 [23].

III. Results and Methods

The fauna community at the Hakri River during 2015 season was identified with a total of 69 taxa, representing five classes (Table 1). Although this area was not wide, but the fauna were very diverse with 47 taxa, representing five kingdoms. Mammals accounted for 12 taxa for four seasons within the studied areas. Birds (Aves) exhibited the greatest species diversity with 20 taxa identified, followed by invertebrates (15 taxa). Reptiles/amphibians (Sauropsida/Amphibia) were the most poorly represented of the terrestrial vertebrate groups, accounting for only 11 taxa. Fish represented by 11 taxa. The mean numbers of species were 34 taxa within the St. A, 32 taxa within the St. B, 35 taxa within the St. C, and 39 taxa within the St. D.

Mammals, birds, and reptiles/amphibians were shown with the relative high individual density or abundance in upper region (station A) of river across areas (Table 2). Fish and invertebrate animals were shown with the relative high individual density or abundance in low region (station D). Shannon-Weaver indices (H´) for mammals and birds at upper region were higher than those of low region. Richness indices for animal taxa were also varied among the stations and seasons. Although evenness indices for five animal kingdoms during seasons were different from each other, there were not shown significant differences ($p < 0.05$). Berger-Parker's index (BPI) for mammals was varied from 0.121 (invertebrates at Station A) to 0.304 (reptile /amphibian at Station A). In order to assess macro-scale spatial variability of the animal community at the Hakri River, I analyzed distributions of species richness, diversity, and evenness of large taxonomic groups as well as four station compositions along a geographic distances (Tables 2 and 3). Shannon-Weaver indices (H´) of diversity for mammals was varied from 1.721 to 2.120. H´ for mammals also varied among the stations and season. H´ values for upper regions of river were higher than those of lower regions. Low region of river was high H´ for birds and fish. Upper region was considerable high richness in mammals and birds. Although evenness indices for five animal kingdoms were different from each other, there were not shown significant differences ($P<0.05$). BHI values for four kingdoms except invertebrates were low at high region, meaning dominant species were different according to stations or seasons.

Table 1. Biological diversity index for mammals, birds, and reptile/amphibians in the studied areas

Indices	Mammal				Bird				Reptile /Amphibian			
	St. A	St. B	St. C	St. D	St. A	St. B	St. C	St. D	St. A	St. B	St. C	St. D
No. of species	10	9	8	6	14	17	13	12	8	7	6	6
Diversity												
H'	2.119	2.120	1.996	1.721	2.457	2.670	2.408	2.363	1.877	1.762	1.640	1.718
N1	8.321	8.333	7.360	5.591	11.671	14.444	11.116	10.625	6.532	5.825	5.031	5.765
N2	8.279	9.778	8.775	6.955	11.629	14.642	11.283	12.059	6.088	5.627	5.031	5.765
Richness												
BPI	0.262	0.212	0.222	0.278	0.229	0.179	0.216	0.195	0.304	0.286	0.293	0.245
R1	2.408	2.288	2.124	1.730	3.358	3.805	3.052	2.962	1.828	1.605	1.346	1.285
R2	1.543	1.567	1.540	1.414	2.021	2.077	1.820	1.874	1.180	1.080	0.937	0.857
Evenness												
E1	0.920	0.965	0.960	0.961	0.931	0.942	0.939	0.951	0.902	0.906	0.915	0.959
E2	0.832	0.926	0.920	0.932	0.834	0.850	0.855	0.885	0.816	0.832	0.859	0.929
E3	0.813	0.917	0.909	0.918	0.821	0.840	0.843	0.875	0.790	0.804	0.831	0.915
E4	0.995	1.173	1.192	1.244	0.996	1.014	1.015	1.135	0.932	0.966	0.976	1.034
E5	0.994	1.197	1.222	1.297	0.996	1.015	1.017	1.149	0.920	0.959	0.970	1.041

Table 2. Biological diversity index for fishes and invertebrates in the studied areas

Indices	Fish				Invertebrates			
	St. A	St. B	St. C	St. D	St. A	St. B	St. C	St. D
No. of species	10	8	8	11	12	11	12	15
Diversity								
H'	2.159	1.882	1.937	2.230	2.415	2.601	2.384	2.583
N1	8.658	6.566	6.937	9.297	11.185	9.578	10.851	13.233
N2	8.966	6.703	7.500	9.719	13.895	11.625	12.424	14.571
Richness								
BPI	0.250	0.250	0.222	0.204	0.121	0.149	0.195	0.173
R1	2.440	2.020	1.953	2.569	3.146	2.912	2.962	3.543
R2	1.581	1.414	1.333	1.571	2.089	1.976	1.874	2.081
Evenness								
E1	0.937	0.905	0.931	0.930	0.972	0.942	0.959	0.954
E2	0.866	0.821	0.867	0.845	0.932	0.871	0.904	0.882
E3	0.851	0.795	0.848	0.830	0.926	0.858	0.896	0.874
E4	1.035	1.021	1.081	1.045	1.242	1.214	1.145	1.101
E5	1.040	1.025	1.095	1.051	1.266	1.239	1.160	1.109

The values of ß-diversity for animals were varied from 0.180 for reptiles/amphibians to 0.233 for birds (Fig. 2). For the community as a whole, the values of ß-diversity were the low (from 0.156 for St. D to 0.205 for St. A) (Fig. 3). They indicated that heterogeneity in species compositions among the replicates were high. It is usually assumed that differences in the biological characters and habitat quality of animals in the environment are the basis for their ability. Alternatively, isolation would be a game of chance, where stochastic principles would favor the isolation of more abundant community members and sample heterogeneity would determine seasonal migration (migratory birds) for favor habitat. In addition, many numbers of reptiles/amphibians were different from each other between seasons because

generally begin hibernation in late fall. There were high taxonomic homogeneity of the mammals and fish community in between four seasons and similar trends in seasonal development of animals at riparian and channels of the same river. However, distribution of biological diversity and richness showed a statistically significant upper-low regions different (p <0.05).

Table 3. Ecological distance (upper diagonal) based on Bray-Curtis' formulae analysis and geographic distances (km) (low diagonal) among four stations at the Hakri River

Station	St. A	St. B	St. C	St. D
St. A	-	0.011	0.535	0.639
St. B	0.675	-	0.331	0.551
St. C	1.259	0.584	-	0.007
St. D	1.871	1.196	0.612	-

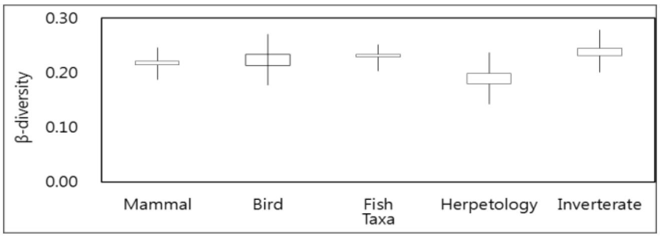

Figure 2: Occurrence index (β-diversity) for five animal kingdoms at four stations.

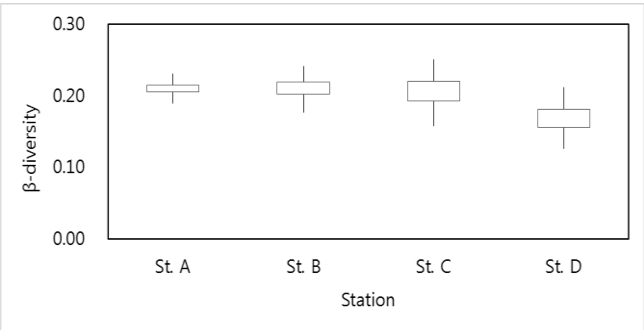

Figure 3: Occurrence index (β-diversity) of four stations for five animal kingdoms.

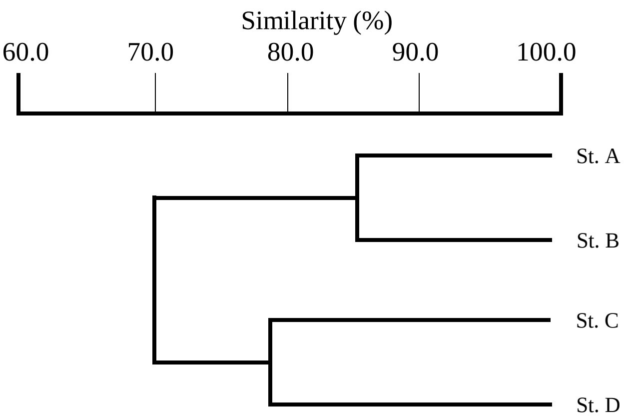

Figure 4: A phenogram showing the animal distribution relationships among four stations at the Hakri River.

The Bray-Curtis' distances were calculated from differences in abundance of each species according to geographic distances among four stations at the Hakri River (Table 4). Neighboring stations such as St. C and St. D had the similar species composition and the highest remote populations (St. A and St. D) did not share any species.

Clustering of four stations, using the NJ algorithm, was performed based on the matrix of calculated distances (Fig. 4). Four stations of the Hakri River were well separated each other. The dendrogram showed two distinct groups; St. A and St. B clade and the other stations (St. C and St. D).

Different indices of species diversity, richness, and evenness were reflected different aspects of biodiversity. An index based on overall abundance exclusively measures a single component of biodiversity [24]. This makes it easy to understand and interpret. However, it should be used together with an index that measures species evenness, such as the Shannon index or Simpson's index. If an index is obtained by averaging relative abundance indices across species, then the geometric mean has much better properties than the arithmetic mean. The general similarity among diversity patterns of different taxa with latitude and region suggests that prehistorically these patterns have been controlled primarily by factors operating over large spatial and temporal scales.

IV. Conclusion

Environmental problems have occurred in the Hakri River because human activities push ecosystems so far. That is, human activities strain the limits of resilience, gradually altering the biotic and abiotic conditions of the environment, damage can be severe. Many artificial actions such as overuse of fertilizer for agriculture reduced the water's natural filtration action and eliminated many riparian species for Direct-stream Rivers Project at their habitat in the Hakri River.

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